What is Claimed:

1. A method for manufacturing a microstructure device, which includes at least one fine feature on an existing feature, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:

a) providing a microstructure device preform including the existing feature on a top surface;

b) profiling a portion of the top surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;

c) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the microstructure device preform based on the topographical image;

d) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the microstructure device preform in the image coordinate system using the topographical image;

e) aligning a probe tip of an NSOM probe of the NSOM over a portion of the existing feature of the microstructure device preform using the coordinates of the reference point and the orientation of the existing feature determined in step (d); and

f) machining the top surface of the microstructure device preform with the micro-machining laser to form the at least one fine feature on the existing feature, completing the microstructure device.

2. The method according to claim 1, wherein step (b) includes the steps of:

b1) selecting the portion of the top surface of the microstructure device preform to be profiled;

b2) aligning the probe tip of the NSOM over a point in the selected portion of the top surface of the microstructure device preform;

b3) determining a distance between the probe tip of the NSOM and the top surface of the microstructure device preform;

b4) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the microstructure device preform in a vertical direction;

b5) scanning the probe tip over the selected portion of the top surface while repeating steps (b3) and (b4) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

b6) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the microstructure device preform moved in step (b4).

3. The method according to claim 2, wherein step (b1) includes the steps of:

b1a) optically imaging the top surface of the microstructure device preform to produce an optical image;

b1b) identifying an area of the top surface that includes the existing feature from the optical image;

b1c) selecting the area identified in step (b1b) as the portion of the top surface to be profiled.

4. The method according to claim 2, wherein the step of determining the distance between the probe tip and the top surface of the microstructure device preform includes detecting an atomic force between the probe tip and the top surface.

5. The method according to claim 2, wherein step (b3) includes the steps of:

b3a) generating a periodic oscillation of the NSOM probe of the NSOM in the vertical direction;

b3b) detecting at least one of;

a period of the periodic oscillation of the NSOM probe; or

an amplitude of the periodic oscillation of the NSOM probe; and

b3c) determining the distance between the probe tip and the top surface based on changes in the at least one of the period or the amplitude of the periodic oscillation detected in step (b3b).

6. The method according to claim 2, wherein the step of controlling the distance between the probe tip and the top surface of the microstructure device preform includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform based on the distance between the probe tip and the top surface determined in step (b3).

7. The method according to claim 2, wherein:

the profiling distance is in the range of up to about 50nm; and

the distance between the probe tip of the NSOM and the top surface of the microstructure device preform is controlled in step (b4) with a tolerance of less than 5nm.

8. The method according to claim 2, wherein step (b5) includes:

b5a) moving the probe tip back and forth across the selected portion in a first horizontal direction to perform a plurality of passes; and

b5b) moving the probe tip a predetermined distance in a second horizontal direction between each consecutive pair of passes, the second horizontal direction being different from the first horizontal direction, thereby scanning the selected portion of the top surface.

9. The method according to claim 1, wherein the image coordinate system includes X, Y, and Z coordinates for the profiled portion of the top surface of the microstructure device preform, the X, Y, and Z coordinates being respectively scaled to corresponding X, Y, and Z settings of the NSOM determined in step (b).

10. The method according to claim 1, wherein:

step (d) further includes the steps of;

d1) determining coordinates of two calibration points of the top surface of the microstructure device preform in the image coordinate system using the topographical image, the two calibration points being a predetermined distance apart; and

d2) calculating a conversion factor between the image coordinate system and a spatial coordinate system of the microstructure device preform; and

aligning the probe tip of the NSOM over the portion of the existing feature in step (e) further includes using the conversion factor between the image coordinate system and the spatial coordinate system determined in step (d2).

11. The method according to claim 1, wherein step (e) includes the steps of:

e1) aligning the probe tip horizontally over a portion of the existing feature of the microstructure device preform; and

e2) controlling the distance between the probe tip and the top surface of the microstructure device preform to be substantially a machining distance based on the topographical image of the portion of the top surface of the microstructure device preform and the image coordinate system.

12. The method according to claim 11, wherein the step of controlling the distance between the probe tip and the top surface of the microstructure device preform to be substantially the machining distance includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform.

13. The method according to claim 11, wherein:

the machining distance is in a range of up to half of a peak wavelength of light generated by the micro-machining laser; and

the distance between the probe tip of the NSOM probe and the top surface of the microstructure device preform is controlled in step (e2) with a tolerance of less than 5nm.

14. The method according to claim 1, wherein step (f) includes the steps of:

f1) using the micro-machining laser to generate pulses of laser light;

f2) coupling the pulses of laser light into the NSOM probe;

f3) coupling a near-field mode portion of the pulses of laser light through the probe tip of the NSOM probe and onto the portion of the existing feature of the microstructure device preform over which the probe tip is aligned to machine the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned; and

f4) aligning the probe tip over another portion of the existing feature and repeating steps f1, f2, f3, and f4 until the microstructure device is completed.

15. The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator and an attenuator; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial fluence; and

f1b) using the attenuator to control the fluence of the initial pulses of laser light, thereby producing the pulses of laser light having a predetermined near-field machining fluence.

16. The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator and a polarization controller; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial polarization; and

f1b) using the polarization controller to adjust the initial polarization of the initial pulses of laser light to a substantially circular polarization.

17. The method according to claim 14, wherein:

the micro-machining laser includes a laser oscillator to generate the pulses of laser light in step (f1) and a shutter to control emission of the pulses; and

step (f4) includes the steps of:

f4a) moving the at least one of the NSOM probe or the microstructure device preform to scan the probe tip over a region of the top surface of the microstructure device preform including portions of the existing feature in which the at least one fine feature is to be machined;

f4b) opening the shutter when the probe tip is scanned over the portions of the existing feature in which the at least one fine feature is to be machined, thereby allowing machining of the at least one fine feature; and

f4c) closing the shutter when the probe tip is scanned over other areas of the scanned region of the top surface of the microstructure device preform, thereby preventing machining of the other areas of the scanned region.

18. The method according to claim 1, wherein machining the top surface of the microstructure device preform in step (f) includes at least one of:

ablating device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

laser-assisted chemical vapor depositing deposition material on the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

exposing photoresist on the top surface of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

changing an index of refraction of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned;

altering a lattice structure of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned; or

changing a chemical composition of the device material of the microstructure device preform in the portion of the existing feature over which the probe tip is aligned.

19. The method according to claim 1, wherein the micro-machining laser is one of an ultrafast laser, a pulsed solid state laser, a pulsed dye laser, a microchip laser, a pulsed CO_2 laser, or an excimer laser.

20. The method according to claim 1, wherein the microstructure device to be manufactured is at least one of a microstructure mold, a quantum cellular automaton, a coupled quantum dot device, a resonant tunneling device, a multifunction optical array, a diffractive optical element, a beam shaper, a microlens array, an optical diffuser, a beam splitter, a laser diode corrector, a fine pitch grating, a photonic crystal, a micro-electrical-mechanical system, micro-circuitry, a polymerase chain reaction microsystem, a biochip for detection of hazardous chemical and biological agents, a high-throughput drug screening and selection microsystem, a micro-surface-acoustic-wave device, or a micro-mechanical oscillator.

21. The method according to claim 1, wherein:

the microstructure device to be manufactured is a micro-mechanical oscillator; and

a resonance spectrum of the micro-mechanical oscillator is tuned by the at least one fine feature machined on the existing feature.

22. The method according to claim 21, wherein:

step (a) includes the steps of;

a1) activating the micro-mechanical oscillator;

a2) determining an initial resonance spectrum of the micro-mechanical oscillator;

a3) comparing the initial resonance spectrum determined in step (a2) to a predetermined resonance spectrum; and

a4) determining a desired shape on the existing feature of the at least one fine feature based on the comparison in step (a3); and

step (f) includes machining the at least one fine feature to have the desired shape on the existing feature determined in step (a4) with the micro-machining laser.

23. The method according to claim 1, wherein:

the microstructure device to be manufactured is a photonic crystal;

the at least one fine feature to be machined is a defect; and

a transmission spectrum of the photonic crystal is tuned by the defect.

24. The method according to claim 23, wherein:

step (a) includes the steps of;

a1) determining the transmission spectrum of the photonic crystal;

a2) comparing the transmission spectrum determined in step (a1) to a predetermined transmission spectrum; and

a3) determining a shape of the defect and a defect location based on the comparison in step (a2); and

step (f) includes machining the defect at the defect location and having the shape determined in step (a3).

25. A method for mass customizing a plurality of microstructures with a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, each microstructure having at least one of a plurality of customization features, the method comprising the steps of:

a) providing a plurality of microstructure preforms, each microstructure preform including a top surface and an existing feature on the top surface;

b) selecting a microstructure preform from the plurality of microstructure preforms and at least one customization feature from the plurality of customization features, the at least one customization feature to be located on the existing feature;

c) mounting the selected microstructure preform in the NSOM;

d) profiling a portion of the top surface of the selected microstructure preform with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the existing feature;

e) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the selected microstructure preform based on the topographical image;

f) determining coordinates of a reference point and an orientation of the existing feature of the top surface of the selected microstructure preform in the image coordinate system using the topographical image;

g) aligning a probe tip of an NSOM probe of the NSOM over a portion of the existing feature of the selected microstructure preform using the coordinates of the reference point and the orientation of the existing feature determined in step (f);

h) machining the top surface of the selected microstructure preform with the micro-machining laser to form the at least one customization feature selected in step (b) to form a customized microstructure; and

i) repeating steps (b), (c), (d), (e), (f), (g), and (h) for each of the plurality of microstructure preforms provided in step (a).

26. The method according to claim 25, wherein step (d) includes the steps of:

d1) selecting the portion of the top surface of the selected microstructure preform to be profiled;

d2) aligning the probe tip of the NSOM over a point in the selected portion of the top surface of the selected microstructure preform;

d3) determining a distance between the probe tip of the NSOM and the top surface of the selected microstructure preform;

d4) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the selected microstructure preform in a vertical direction;

d5) scanning the probe tip over the selected portion of the top surface while repeating steps (d3) and (d4) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

d6) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the selected microstructure preform moved in step (d4).

27. The method according to claim 26, wherein step (d1) includes the steps of:

d1a) optically imaging the top surface of the selected microstructure preform to produce an optical image;

d1b) identifying an area of the top surface that includes the existing feature from the optical image;

d1c) selecting the area identified in step (b1b) as the portion of the top surface to be profiled.

28. The method according to claim 26, wherein the step of determining the distance between the probe tip and the top surface of the selected microstructure preform includes detecting an atomic force between the probe tip and the top surface.

29. The method according to claim 26, wherein step (d3) includes the steps of:

d3a) generating a periodic oscillation of the NSOM probe of the NSOM in the vertical direction;

d3b) detecting at least one of;

a period of the periodic oscillation of the NSOM probe; or

an amplitude of the periodic oscillation of the NSOM probe; and

d3c) determining the distance between the probe tip and the top surface based on changes in the at least one of the period or the amplitude of the periodic oscillation detected in step (d3b).

30. The method according to claim 26, wherein the step of controlling the distance between the probe tip and the top surface of the selected microstructure preform includes using a Z motion stage to control a vertical position of one of the NSOM probe or the selected microstructure preform based on the distance between the probe tip and the top surface determined in step (d3).

31. The method according to claim 26, wherein:

the profiling distance is in the range of up to about 50nm; and

the distance between the probe tip of the NSOM and the top surface of the selected microstructure preform is controlled in step (d4) with a tolerance of less than 5nm.

32. The method according to claim 26, wherein step (d5) includes:

d5a) moving the probe tip back and forth across the selected portion in a first horizontal direction to perform a plurality of passes; and

d5b) moving the probe tip a predetermined distance in a second horizontal direction between each consecutive pair of passes, the second horizontal direction being different the first horizontal direction, thereby scanning the selected portion of the top surface.

33. The method according to claim 25, wherein the image coordinate system includes X, Y, and Z coordinates for the profiled portion of the top surface of the selected microstructure preform, the X, Y, and Z coordinates being respectively scaled to corresponding X, Y, and Z settings of the NSOM determined in step (d).

34. The method according to claim 25, wherein:

step (f) further includes the steps of;

f1) determining coordinates of two calibration points of the top surface of the selected microstructure preform in the image coordinate system using the topographical image, the two calibration points being a predetermined distance apart; and

f2) calculating a conversion factor between the image coordinate system and a spatial coordinate system of the selected microstructure preform; and

aligning the probe tip of the NSOM over the portion of the existing feature in step (g) further includes using the conversion factor between the image coordinate system and the spatial coordinate system determined in step (f2).

35. The method according to claim 25, wherein step (g) includes the steps of:

g1) aligning the probe tip horizontally over a portion of the existing feature of the selected microstructure preform; and

g2) controlling the distance between the probe tip and the top surface of the selected microstructure preform to be substantially a machining distance based on the topographical image of the portion of the top surface of the selected microstructure preform and the image coordinate system.

36. The method according to claim 35, wherein the step of controlling the distance between the probe tip and the top surface of the selected microstructure preform to be substantially the machining distance includes using a Z motion stage to control a vertical position of one of the NSOM probe or the selected microstructure preform.

37. The method according to claim 35, wherein:

the machining distance is in a range of up to half of a peak wavelength of light generated by the micro-machining laser; and

the distance between the probe tip of the NSOM probe and the top surface of the selected microstructure preform is controlled in step (g2) with a tolerance of less than 5nm.

38. The method according to claim 25, wherein step (h) includes the steps of:

h1) using the micro-machining laser to generate pulses of laser light;

h2) coupling the pulses of laser light into the NSOM probe;

h3) coupling a near-field mode portion of the pulses of laser light through the probe tip of the NSOM probe and onto the portion of the existing feature of the

selected microstructure preform over which the probe tip is aligned to machine the top surface of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned; and

h4) aligning the probe tip over another portion of the existing feature and repeating steps h1, h2, h3, and h4 until the customized microstructure is completed.

39. The method according to claim 38, wherein:

the micro-machining laser includes a laser oscillator and an attenuator; and

step (h1) includes the steps of:

h1a) using the laser oscillator to generate initial pulses of laser light having an initial fluence; and

h1b) using the attenuator to control the fluence of the initial pulses of laser light, thereby producing the pulses of laser light having a predetermined near-field machining fluence.

40. The method according to claim 38, wherein:

the micro-machining laser includes a laser oscillator and a polarization controller; and

step (h1) includes the steps of:

h1a) using the laser oscillator to generate initial pulses of laser light having an initial polarization; and

h1b) using the polarization controller to adjust the initial polarization of the initial pulses of laser light to a substantially circular polarization.

41. The method according to claim 38, wherein:

the micro-machining laser includes a laser oscillator to generate the pulses of laser light in step (h1) and a shutter to control emission of the pulses; and

step (h4) includes the steps of:

h4a) moving the at least one of the NSOM probe or the selected microstructure preform to scan the probe tip over a region of the top surface of the selected microstructure preform including machining portions of the existing feature in which the at least one customization feature selected in step (b) is to be machined;

h4b) opening the shutter when the probe tip is scanned over the machining portions of the existing feature, thereby allowing machining of the at least one customization feature selected in step (b); and

h4c) closing the shutter when the probe tip is scanned over other areas of the scanned region of the top surface of the selected microstructure preform, thereby preventing machining of the other areas of the scanned region.

42. The method according to claim 25, wherein machining the top surface of the selected microstructure preform in step (h) includes at least one of:

ablating device material of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned;

laser-assisted chemical vapor depositing deposition material on the top surface of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned;

exposing photoresist on the top surface of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned;

changing an index of refraction of the device material of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned;

altering a lattice structure of the device material of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned; or

changing a chemical composition of the device material of the selected microstructure preform in the portion of the existing feature over which the probe tip is aligned.

43. The method according to claim 25, wherein the micro-machining laser is one of an ultrafast laser, a pulsed solid state laser, a pulsed dye laser, a microchip laser, a pulsed CO_2 laser, or an excimer laser.

44. The method according to claim 25, wherein the plurality of microstructures to be mass customized include at least one of a microstructure mold, a quantum cellular automaton, a coupled quantum dot device, a resonant tunneling device, a multifunction optical array, a diffractive optical element, a beam shaper, a microlens array, an optical diffuser, a beam splitter, a laser diode corrector, a fine pitch grating, a photonic crystal, a micro-electrical-mechanical system, micro-circuitry, a polymerase chain reaction microsystem, a biochip for detection of hazardous chemical and biological agents, a high-throughput drug screening and selection microsystem, a micro-surface-acoustic-wave device, or a micro-mechanical oscillator.

45. A method for repairing a microstructure with a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the microstructure including a defect on a top surface, the method comprising the steps of:

a) mounting the defective microstructure in the NSOM;

b) profiling a portion of the top surface of the defective microstructure with the NSOM to produce a topographical image of the portion of the top surface, the portion of the top surface selected such that the topographical image includes a representation of the defect;

c) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of top surface of the defective microstructure based on the topographical image;

d) determining coordinates of the defect of the top surface of the defective microstructure in the image coordinate system using the topographical image;

e) aligning a probe tip of an NSOM probe of the NSOM over a portion of the defect of the defective microstructure using the coordinates of the defect determined in step (d); and

f) machining the top surface of the defective microstructure with the micro-machining laser to repair the defect of the defective microstructure.

46. The method according to claim 45, wherein step (b) includes the steps of:

b1) selecting the portion of the top surface of the defective microstructure to be profiled;

b2) aligning the probe tip of the NSOM over a point in the selected portion of the top surface of the defective microstructure;

b3) determining a distance between the probe tip of the NSOM and the top surface of the defective microstructure;

b4) controlling the distance between the probe tip and the top surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the defective microstructure in a vertical direction;

b5) scanning the probe tip over the selected portion of the top surface while repeating steps (b3) and (b4) to maintain the distance between the probe tip and the top surface substantially equal to the profiling distance;

b6) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the defective microstructure moved in step (b4).

47. The method according to claim 46, wherein step (b1) includes the steps of:

b1a) optically imaging the top surface of the defective microstructure to produce an optical image;

b1b) identifying an area of the top surface that includes the defect from the optical image;

b1c) selecting the area identified in step (b1b) as the portion of the top surface to be profiled.

48. The method according to claim 46, wherein the step of determining the distance between the probe tip and the top surface of the defective microstructure includes detecting an atomic force between the probe tip and the top surface.

49. The method according to claim 46, wherein step (b3) includes the steps of:

b3a) generating a periodic oscillation of the NSOM probe of the NSOM in the vertical direction;

b3b) detecting at least one of;

a period of the periodic oscillation of the NSOM probe; or

an amplitude of the periodic oscillation of the NSOM probe; and

b3c) determining the distance between the probe tip and the top surface based on changes in the at least one of the period or the amplitude of the periodic oscillation detected in step (b3b).

50. The method according to claim 46, wherein the step of controlling the distance between the probe tip and the top surface of the defective microstructure includes using a Z motion stage to control a vertical position of one of the NSOM probe or the defective microstructure based on the distance between the probe tip and the top surface determined in step (b3).

51. The method according to claim 46, wherein:

the profiling distance is in the range of up to about 50nm; and

the distance between the probe tip of the NSOM and the top surface of the defective microstructure is controlled in step (b4) with a tolerance of less than 5nm.

52. The method according to claim 45, wherein step (b5) includes:

b5a) moving the probe tip back and forth across the selected portion in a first horizontal direction to perform a plurality of passes; and

b5b) moving the probe tip a predetermined distance in a second horizontal direction between each consecutive pair of passes, the second horizontal direction being different from the first horizontal direction, thereby scanning the selected portion of the top surface.

53. The method according to claim 45, wherein the image coordinate system includes X, Y, and Z coordinates for the profiled portion of the top surface of the defective microstructure, the X, Y, and Z coordinates being respectively scaled to corresponding X, Y, and Z settings of the NSOM determined in step (b).

54. The method according to claim 45, wherein:

step (d) further includes the steps of;

d1) determining coordinates of two calibration points of the top surface of the defective microstructure in the image coordinate system using the topographical image, the two calibration points being a predetermined distance apart; and

d2) calculating a conversion factor between the image coordinate system and a spatial coordinate system of the defective microstructure; and

aligning the probe tip of the NSOM over the portion of the defect in step (e) further includes using the conversion factor between the image coordinate system and the spatial coordinate system determined in step (d2).

55. The method according to claim 45, wherein step (e) includes the steps of:

e1) aligning the probe tip horizontally over a portion of the defect; and

e2) controlling the distance between the probe tip and the top surface of the defective microstructure to be substantially a machining distance based on the topographical image of the portion of the top surface of the defective microstructure and the image coordinate system.

56. The method according to claim 55, wherein the step of controlling the distance between the probe tip and the top surface of the defective microstructure to be substantially the machining distance includes using a Z motion stage to control a vertical position of one of the NSOM probe or the defective microstructure.

57. The method according to claim 55, wherein:

the machining distance is in a range of up to half of a peak wavelength of light generated by the micro-machining laser; and

the distance between the probe tip of the NSOM probe and the top surface of the defective microstructure is controlled in step (e2) with a tolerance of less than 5nm.

58. The method according to claim 45, wherein step (f) includes the steps of:

f1) using the micro-machining laser to generate pulses of laser light;

f2) coupling the pulses of laser light into the NSOM probe;

f3) coupling a near-field mode portion of the pulses of laser light through the probe tip of the NSOM probe and onto the portion of the defect of the defective microstructure over which the probe tip is aligned to machine the top surface of the defective microstructure in the portion of the defect over which the probe tip is aligned; and

f4) aligning the probe tip over another portion of the defect and repeating steps f1, f2, f3, and f4 until the microstructure is repaired.

59. The method according to claim 58, wherein:

the micro-machining laser includes a laser oscillator and an attenuator; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light an initial fluence; and

f1b) using the attenuator to control the fluence of the initial pulses of laser light, thereby producing the pulses of laser light having a predetermined near-field machining fluence.

60. The method according to claim 58, wherein:

the micro-machining laser includes a laser oscillator and a polarization controller; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial polarization; and

f1b) using the polarization controller to adjust the initial polarization of the initial pulses of laser light to a substantially circular polarization.

61. The method according to claim 58, wherein:

the micro-machining laser includes a laser oscillator to generate the pulses of laser light in step (f1) and a shutter to control emission of the pulses; and

step (f4) includes the steps of:

f4a) moving the at least one of the NSOM probe or the defective microstructure to scan the probe tip over a region of the top surface of the defective microstructure including the defect;

f4b) opening the shutter when the probe tip is scanned over the defect, thereby allowing machining of the defect; and

f4c) closing the shutter when the probe tip is scanned over other areas of the scanned region of the top surface of the defective microstructure, thereby preventing machining of the other areas of the scanned region.

62. The method according to claim 45, wherein machining the top surface of the defective microstructure in step (f) includes at least one of:

ablating device material of the defective microstructure in the portion of the defect over which the probe tip is aligned;

laser-assisted chemical vapor depositing deposition material on the top surface of the defective microstructure in the portion of the defect over which the probe tip is aligned;

exposing photoresist on the top surface of the defective microstructure in the portion of the defect over which the probe tip is aligned;

changing an index of refraction of the device material of the defective microstructure in the portion of the defect over which the probe tip is aligned;

altering a lattice structure of the device material of the defective microstructure in the portion of the defect over which the probe tip is aligned; or

changing a chemical composition of the device material of the defective microstructure in the portion of the defect over which the probe tip is aligned.

63. The method according to claim 45, wherein the micro-machining laser is one of an ultrafast laser, a pulsed solid state laser, a pulsed dye laser, a microchip laser, a pulsed CO_2 laser, or an excimer laser.

64. The method according to claim 1, wherein the microstructure to be repaired is at least one of a microstructure mold, a quantum cellular automaton, a coupled quantum dot device, a resonant tunneling device, a multifunction optical array, a diffractive optical element, a beam shaper, a microlens array, an optical diffuser, a beam splitter, a laser diode corrector, a fine pitch grating, a photonic crystal, a micro-electrical-mechanical system, micro-circuitry, a polymerase chain reaction microsystem, a biochip for detection of hazardous chemical and biological agents, a high-throughput drug screening and selection microsystem, a micro-surface-acoustic-wave device, or a micro-mechanical oscillator.

65. The method according to claim 45, wherein:

the microstructure to be repaired includes micro-circuitry;

the defect is a short circuit; and

the step of machining the top surface of the defective micro-circuitry in step (f) is ablating device material that forms the short circuit.

66. A method for laser machining a predetermined feature on a surface of a microstructure device preform, using a near field scanning optical microscope (NSOM) laser micromachining system including an NSOM and a micro-machining laser, the method comprising the steps of:

a) laser machining the surface of the microstructure device preform to form a preliminary feature;

b) profiling a portion of the surface of the microstructure device preform with the NSOM to produce a topographical image of the portion of the surface, the portion of the surface selected such that the topographical image includes a representation of the preliminary feature;

c) comparing the representation of the preliminary feature in the topographical image to a predetermined feature representation;

d) determining machining modifications of the preliminary feature needed to form the predetermined feature from the preliminary feature based on the comparison in step (c);

e) laser machining the surface of the microstructure device preform to modify the preliminary feature based on the machining modifications determined in step (d); and

f) repeating steps (b), (c), (d), and (e) until the representation of the preliminary feature substantially matches the predetermined feature representation.

67. The method according to claim 66, wherein step (b) includes the steps of:

b1) selecting the portion of the surface of the microstructure device preform to be profiled;

b2) aligning the probe tip of the NSOM over a point in the selected portion of the surface of the microstructure device preform;

b3) determining a distance between the probe tip of the NSOM and the surface of the microstructure device preform;

b4) controlling the distance between the probe tip and the surface such that the distance is substantially equal to a profiling distance by moving one of the NSOM probe or the microstructure device preform in a vertical direction;

b5) scanning the probe tip over the selected portion of the surface while repeating steps (b3) and (b4) to maintain the distance between the probe tip and the surface substantially equal to the profiling distance;

b6) determining topographical information of the surface based on the vertical movement of the one of the NSOM probe or the microstructure device preform moved in step (b4).

68. The method according to claim 67, wherein the step of determining the distance between the probe tip and the surface of the microstructure device preform includes detecting an atomic force between the probe tip and the surface.

69. The method according to claim 67, wherein step (b3) includes the steps of:

b3a) generating a periodic oscillation of the NSOM probe of the NSOM in the vertical direction;

b3b) detecting at least one of;

a period of the periodic oscillation of the NSOM probe; or

an amplitude of the periodic oscillation of the NSOM probe; and

b3c) determining the distance between the probe tip and the surface based on changes in the at least one of the period or the amplitude of the periodic oscillation detected in step (b3b).

70. The method according to claim 67, wherein the step of controlling the distance between the probe tip and the surface of the microstructure device preform includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform based on the distance between the probe tip and the surface determined in step (b3).

71. The method according to claim 67, wherein:

the profiling distance is in the range of up to about 50nm; and

the distance between the probe tip of the NSOM and the surface of the microstructure device preform is controlled in step (b4) with a tolerance of less than 5nm.

72. The method according to claim 67, wherein step (b5) includes:

b5a) moving the probe tip back and forth across the selected portion in a first horizontal direction to perform a plurality of passes; and

b5b) moving the probe tip a predetermined distance in a second horizontal direction between each consecutive pair of passes, the second horizontal direction being different from the first horizontal direction, thereby scanning the selected portion of the surface.

73. The method according to claim 66, wherein step (c) includes the steps of:

c1) defining an image coordinate system, in terms of settings of the NSOM, for the profiled portion of surface of the microstructure device preform based on the topographical image;

c2) determining coordinates of a reference point and an orientation of the preliminary feature in the image coordinate system using the topographical image;

c3) transforming the predetermined feature representation to the image coordinate system using the coordinates of the reference point and the orientation of the preliminary feature; and

c4) comparing the representation of the preliminary feature to the transformed predetermined feature representation in the image coordinate system.

74. The method according to claim 66, wherein:

laser machining the surface of the microstructure device preform in step (a) includes ablating device material of the microstructure device preform;

step (d) includes the steps of:

d1) identifying regions of the preliminary feature in which a surface height in the representation of the preliminary feature is greater than a corresponding surface height in the predetermined feature representation;

d2) determining differences between the surface height in the representation of the preliminary feature and the corresponding surface height in the predetermined feature representation in the regions identified in step (d1); and

d3) determining the machining modifications to be ablating amounts of the device material of the microstructure device preform equal to the

differences determined in step (d2) in the regions of the preliminary feature identified in step (d1); and

laser machining the surface of the microstructure device preform to modify the preliminary feature based on the machining modifications includes ablating the amounts of device material of the microstructure device preform in the identified regions of the preliminary feature determined in step (d3).

75. The method according to claim 66, wherein:

laser machining the surface of the microstructure device preform in step (a) includes laser-assisted chemical vapor depositing deposition material on the surface of the microstructure device preform;

step (d) includes the steps of:

d1) identifying regions of the preliminary feature in which a surface height in the representation of the preliminary feature is less than a corresponding surface height in the predetermined feature representation;

d2) determining differences between the corresponding surface height in the predetermined feature representation and the surface height in the representation of the preliminary feature in the regions identified in step (d1); and

d3) determining the machining modifications to be laser-assisted chemical vapor depositing amounts of the deposition material on surface of the microstructure device preform equal to the differences determined in step (d2) in the regions of the preliminary feature identified in step (d1); and

laser machining the surface of the microstructure device preform to modify the preliminary feature based on the machining modifications includes laser-assisted chemical vapor depositing the amounts of deposition material on the identified regions of the preliminary feature determined in step (d3).

76. The method according to claim 66, wherein step (e) includes the steps of:

e1) aligning the probe tip horizontally over a portion of the preliminary feature to be modified; and

e2) controlling the distance between the probe tip and the surface of the microstructure device preform to be substantially a machining distance based on the topographical image of the portion of the surface of the microstructure device preform and the machining modifications determined in step (d)

77. The method according to claim 76, wherein the step of controlling the distance between the probe tip and the surface of the microstructure device preform to be substantially the machining distance includes using a Z motion stage to control a vertical position of one of the NSOM probe or the microstructure device preform.

78. The method according to claim 76, wherein:

the machining distance is in a range of up to half of a peak wavelength of light generated by the micro-machining laser; and

the distance between the probe tip of the NSOM probe and the surface of the microstructure device preform is controlled in step (e2) with a tolerance of less than 5nm.

79. The method according to claim 66, wherein step (e) includes the steps of:

e1) using the micro-machining laser to generate pulses of laser light;

e2) coupling the pulses of laser light into the NSOM probe;

e3) coupling a near-field mode portion of the pulses of laser light through the probe tip of the NSOM probe and onto the portion of the preliminary feature of the microstructure device preform over which the probe tip is aligned to machine the surface

of the microstructure device preform in the portion of the preliminary feature over which the probe tip is aligned; and

f4) aligning the probe tip over another portion of the preliminary feature and repeating steps f1, f2, f3, and f4 until the machining modifications are complete.

80. The method according to claim 79, wherein:

the micro-machining laser includes a laser oscillator and an attenuator; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial fluence; and

f1b) using the attenuator to control the fluence of the initial pulses of laser light, thereby producing the pulses of laser light having a predetermined near-field machining fluence.

81. The method according to claim 79, wherein:

the micro-machining laser includes a laser oscillator and a polarization controller; and

step (f1) includes the steps of:

f1a) using the laser oscillator to generate initial pulses of laser light having an initial polarization; and

f1b) using the polarization controller to adjust the initial polarization of the initial pulses of laser light to a substantially circular polarization.

82. The method according to claim 79, wherein:

the micro-machining laser includes a laser oscillator to generate the pulses of laser light in step (f1) and a shutter to control emission of the pulses; and

step (f4) includes the steps of:

f4a) moving the at least one of the NSOM probe or the microstructure device preform to scan the probe tip over a region of the surface of the microstructure device preform including portions of the preliminary feature to be modified;

f4b) opening the shutter when the probe tip is scanned over the portions of the preliminary feature to be modified; and

f4c) closing the shutter when the probe tip is scanned over other areas of the scanned region of the surface of the microstructure device preform, thereby preventing machining of the other areas of the scanned region.

83. The method according to claim 66, wherein the micro-machining laser is one of an ultrafast laser, a pulsed solid state laser, a pulsed dye laser, a microchip laser, a pulsed CO_2 laser, or an excimer laser.